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ABSTRACT

Forty-six tests from the Kit of Factor-Referenced Cognitive Tests, published by the Educational Testing Service, were used in an investigation of the factor structure of the Armed Services Vocational Aptitude Battery. The overall kit contains 72 fairly short tests that have been developed to serve as markers for 23 factors that appear in the literature on cognitive abilities. Subjects were 6,931 Air Force recruits entering training at the Recruit Training Center at Lackland Air Force Base (Texas). The study was designed in such a manner that approximately 1,610 recruits took each of the 46 factor-referenced tests. The gender proportion of the examinees was consistent with that of the general population of Air Force recruits. Each completed test booklet was scored by three independent judges. Twenty-two tests selected from the Kit were reproduced, administered, and scored in very large numbers without encountering problems and without requiring precautions to avoid problems. Some of the remaining tests warranted minor precautionary actions. Other tests were the focus of administration problems that required testing of additional subjects or modifying scoring procedures and answer keys. Suggestions concerning the use of these tests by others interested in research on cognitive abilities are provided. Two data tables are included. (TJH)

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Using the Kit of Factor-Referenced Cognitive Tests: Some Insights and Suggestions

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Abstract

Forty-six tests from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Derman, 1976a), published by the Educational Testing Service (ETS), were used in an investigation of the factor structure of the Armed Services Vocational Aptitude Battery. Experiences associated with the reproduction, administration, and scoring of these tests are discussed. Suggestions concerning the use by others of these tests in research on cognitive abilities are also presented.

Using the Kit oF Factor-Referenced Cognitive Tests:

Some Insights and Suggestions

The Kit of Factor-Referenced Cognitive Tests (sometimes referred to in the literature as the French Kit; Ekstrom, French, Harman, and Derman, 1976a) contains 72 fairly short tests which have been developed to serve as markers for 23 factors that appear in the literature on cognitive abilities. Earlier editions by French (1954) and French, Ekstrom and Price (1963) were updated, modified, and extended to yield the most current (1976a) version. In this current edition, three or more tests are provided for 21 factors. Two tests are provided for each of the remaining two factors. All of the tests are suitable for persons who have reached the ninth grade or higher. A manual (Ekstrom, French, Harman, & Derman, 1976b) provides a brief discussion of each factor and information for scoring each test.

The tests, distributed for research use only, are available in any combination and can facilitate interpretation and comparison of the results of factor-analytic studies of abilities. As Cronbach (1984) has noted, the ETS Kit factors represent a consensus regarding abilities significant for research. Specific factor-referenced tests have been used in research on topics as diverse as the factor structure of the Wechsler Adult Intelligence Scale (Ramsey, 1978), correlates of cognitive mapping ability (Thorndyke & Goldin, 1981), the effect of attitudes on statistics achievement (Elmore & Vasu, 1980), inductive reasoning (Ross, 1977), aptitude-achievement relationships (Burns, 1980), science achievement (Pallrand & Seeker, 1986), and video game performance (Jones, Dunlap, & Bilodeau, 1986). The use of various French Kit tests usually has been on a limited scale and reported matter-of-factly, without evaluation of the instruments.

Forty-six tests (two markers for each of the 23 factors) were selected for use in a study (Augustin, Gillet, Guerrero, & Curran, 1989) examining the factor structure of the Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is a multiple aptitude battery containing 10 subtests that is used by each of the Armed Services for selection and job classification of military recruits. The scope of the ASVAB research provided a significant opportunity to document practical considerations in using the factor-referenced tests. A variety of problems were encountered during the course of test booklet construction and reproduction, pilot administrations, data collection, and scoring of completed tests. Information which will help other Kit users deal with or avoid these problems is presented in this article.

Method

Consistent with a recommendation of the Kit's authors, the ASVAB Factor Reference Study required two marker tests for each factor represented in the Kit. Consequently, it was necessary to select 46 tests from the collection of 72. The tests vary considerably in their required administration times, difficulty levels, ease of administration, ease of scoring, and availability of a scoring key. For this study the most desirable tests were those which were shorter in required administration time, easier to answer correctly, easier to administer, easier to score, and had an

answer key. Because of testing time constraints, required administration time was a heavily weighted criterion for test selection. Table 1 lists the tests used in this study and the cognitive factors they are designed to measure.

Eight test booklets were constructed for the study. Two booklets contained the ten ASVAB subtests. The remaining six booklets each contained seven or eight tests selected from the Kit. The tests were assigned to the booklets to evenly distribute the time requirements, and no tests representing the same factor were allowed in the same booklet. Tests within each booklet were ordered from least difficult at the front of the booklet to most difficult at the rear. When two or more tests had the same difficulty level, tests were ordered by time requirement, from shortest to longest. The factor-referenced tests were printed on 70# white vellum offset paper to achieve a high degree of opacity. This was particularly important for the reproduction of associative memory and visual memory tests and tests involving illustrations, such as the Gestalt Completion Test and the Concealed Words Test.

Subjects in the study were 6931 Air Force recruits entering training at the Recruit Training Center at Lackland AFB, Texas. Plans were developed to administer two booklets to each examinee in a matrix sampling plan. Booklets were paired in all possible combinations so that each booklet was administered with every other booklet. The operational ASVAB was administered at both the beginning and end of data collection so that the effect of time of year upon test performance could be examined. Since each booklet was paired with the seven others, approximately 1610 recruits took each of the 46 factor-referenced tests. Each booklet pairing was administered to 230 recruits. Of the 230 examinees for each pairing, 191 were male and 39 were female, consistent with gender proportions of Air Force recruits. Examinees recorded their answers for all factor-referenced tests directly in the test booklets.

Each completed test booklet was scored by three independent judges due to the subjective nature of the scoring of a number of the tests. To insure the independence of the scorings, the three judges or raters were not allowed to make marks in the booklets but were provided transparencies that could be marked on and easily wiped off for reuse. For ease of data entry, test scores were entered by the raters on the back cover of the test booklet which provided spaces for each test score along with the rater's initials.

The 46 factor-referenced tests are very diverse in their formats and range from objective multiple-choice vocabulary tests to pattern copying and sentence writing tests which require careful inspection and considerable judgment by raters during scoring. The Manual for Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Derman, 1976b) does provide information on scoring many of the tests. For some tests answer keys are provided; for others, preparation of an answer key or set of scoring procedures is left entirely to the test user. Therefore, a special scoring manual was developed for each of the six factor-referenced test booklets. Each manual contained general guidelines as well as step-by-step instructions for scoring each of the seven or eight tests within a specific booklet. The manuals also contained templates that were constructed to speed up and enhance

the accuracy of scoring of the following objective tests with unnumbered items: Addition Test, Picture-Number Test, Number Comparison Test, Card Rotations Test, Figure Classification Test, Subtraction & Multiplication Test, Hidden Patterns Test, and the Maze Tracing Speed Test. In addition, the manuals contained tables that could be used to determine scores corrected for guessing where necessary.

Each marker test contains two separately timed parts, except for the memory span tests which contain only one part. Each rater indicated the score for both parts which were summed for a total score. The final test score for an individual was an average of the total scores from the three judges.

Test Observations

Twenty-two tests selected from the Kit were reproduced, administered, and scored in very large numbers without encountering problems and without requiring precautions to avoid problems. Some of the remaining selected tests warranted minor precautionary actions. Other tests were the focus of administration problems which required testing of additional subjects or modifying scoring procedures and answer keys.

Reproduction

As part of the test review process, the investigators administered, completed, and scored all the tests among themselves. During this screening process, irregularities were identified on the ETS-supplied master copies of several tests. All required changes were made before test reproduction and after consultation with and approval from Kit author Ruth Ekstrom, Senior Research Scientist at ETS.

The appearance of the example in the instructions for the Making Groups Test is inconsistent with the appearance of the items in Part 1 and Part 2 of this test. The example itself and the inconsistency with test items was a source of confusion. Altering the spacing of the example, so that it more closely resembled the actual test items, eliminated a potential point of confusion for the examinees. Similarly, the Storage Test was found to contain an example on its instruction page which is inconsistent with the appearance of the actual test items. On the instruction page, dashed lines were added to the faces of the three containers presented as examples of correct solutions. Addition of these dashes made the appearance of the examples consistent with the containers in Part 1 and Part 2 of the test and removed another substantial point of confusion.

The correct answer for item 25 in the Vocabulary I Test was misprinted as one word rather than two. To avoid confusion among examinees, this noteworthy typographical error was carefully corrected prior to reproduction of this test.

Administration

Pilot work and large scale administration of all 46 tests alerted investigators to the need for special attention during the administration of some tests. The Finding A's Test was involved in the most frequently occurring test administration problem. Each of the two separately timed parts

of this test has four pages of items which are very similar in appearance. the numbered test parts are poorly marked. During several initial test sessions, many recruits mistook the third and fourth pages of Part 1 as the first two pages of Part 2 when they were instructed to stop work on Part 1 and begin Part 2. Consequently they spent twice the designated time on Part 1 and left Part 2 unattempted. Announcing the correct page numbers for each part during test administration and extremely close monitoring by proctors were precautions taken that virtually eliminated this problem from subsequent sessions. More prominent labeling of the test parts would be helpful.

The Auditory Number Span Test and Auditory Letter Span Test also required an addition to the test instructions. After the last instruction printed on the cover page, the test administrator read "One more special instruction: Indicate you have completed writing down a series by placing your pencil on your desk." The administrator was instructed to carefully observe the examinees after each series and allow adequate time for all to respond, but no more than 20 seconds. The time limit was established as a result of pilot administrations of these tests. Requiring the examinees to put down their pencils after responding to each series provided a cue to the administrator and eliminated the temptation of some examinees in a group setting to write while the series were being read.

Recording the memory span test items on an audiotape to standardize administration was considered during planning of the research. However, consistent and accurate reading of the items was easily achieved through practice by the test administrators. The risks of poor sound quality and equipment breakdowns contributed to the decision to use "live" recitation of the items rather than a taped presentation.

The Calendar Test includes a page containing a calendar that is used for answering items. ETS instructions indicate that the calendar page can be torn out. Since it was preferable for the booklets to remain intact, the instruction to tear out the calendar page was deleted and the booklets were printed so that the calendar faced the page that contained the items.

The Picture-Number Test, Object-Number Test, Building Memory Test, and Map Memory Test all follow a similar format. Each test consists of two parts, with two pages per part. The first page in each part is a memory or study page which contains the test stimuli to be remembered by the examinee. The second page contains the test items. To insure that examinees in a large group setting did not look back at the memory/study pages while responding to the test items, very close proctoring was required during these tests. While careful proctoring is desirable during the administration of all factor-referenced tests, special attention to proctoring is recommended whenever other researchers use these memory tests. As an added precaution against the examinees turning to the second page that contained test items, the instructions "DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO" was included at the bottom of the study page for the Building Memory Test and Map Memory Test.

Scoring

The experiences of the investigators and test scorers suggested that the factor-referenced tests can be placed in three general categories of

ease/difficulty in scoring, as indicated in Table 1. Many future Kit users will want to consider ease of scoring when selecting the test for a particular factor. Category 1 tests have a comprehensive answer key for scoring objective test items. Examinees' responses to test items are usually in the form of circles around, or X's on, the responses chosen as correct. A few of these tests involve writing letters or words. Only occasional interpretation of examinees' answer marks or handwriting is required. Consequently the scoring process is relatively straightforward.

Category 2 encompasses tests which possess noncomprehensive answer keys for test items. Some items have more than one correct answer, and new solutions or acceptable answers, beyond those provided by ETS, were found during scoring. These tests often require handwriting which must be deciphered by the scorer. Table 2 lists the tests and items which have additional correct answers not contained in the keys in the Kit manual. Copies of the specific additions have been submitted to ETS for their files.

Insert Table 1 here

Insert Table 2 here

No answer keys are available for tests in category 3, due to the open-ended nature of the test items. Only a set of guidelines and examples are provided to scorers. Substantial scorer judgment is required and deciphering of handwriting is often necessary. Consequently, scoring tests in category 3 is more problematic and differences among scorers can be more frequent and of greater magnitude. If other researchers select category 3 tests to measure factors, scoring will be more intense and require more time and resources.

Important observations can also be made about the scoring of particular tests. Although it looks fairly simple, the Copying Test proved to be one of the most time-consuming tests to score. The Kit manual leaves preparation of a key to the user. For this study, templates were made, using transparent plastic, to enhance scoring speed and accuracy. Even with these aids, many judgments regarding the preciseness or fidelity of copied patterns must be made. Consequently it was also necessary to establish specific rules on how to score occurrences such as correct patterns that also include stray lines or additional dots, and quickly drawn patterns that may have curved lines that just miss a dot that should be intersected.

Scoring procedures and keys in the ETS Manual acknowledge the complexity of scoring the ten items in the Toothpicks Test. The key provides 88 solutions that follow unique rules, and 61 of these are noted as having reflections and/or rotations. Following ETS advice, families of solutions were presented in the scoring manual developed for the ASVAB Factor Reference Study. (A family is a solution which follows a unique rule, plus all its rotations and reflections, if any.) Many new solutions emerged during the process of scoring more than 1600 copies of the Toothpicks Test. At the completion of the scoring, 54 new unique solutions had been identified, for a total of 142. Also two solutions not designated by ETS as having rotations were found to have 180^{o} rotations. The scoring manual prepared for the ASVAB research contained a total of 340 acceptable solutions grouped into the

142 families. A complete directory of acceptable solutions was forwarded to ETS.

The Number Comparison Test requires quick comparisons of pairs of numbers and a judgment on whether or not the numbers in each pair are the same. For numbers that are not the same, examinees place an X on the line between them. When the numbers in a pair are the same, no mark is made on the test page. This creates a scoring problem not addressed in the ETS manual: there is no way of confidently distinguishing between unattempted items at the end of a test and items that the examinee judged as the same and intentionally left blank. ETS acknowledged this problem and suggested that the investigators consider the last item marked with an X as the last item attempted and judged. A modification of the instructions might be more appropriate and yield higher quality data for future users of this test. At the end of the one and one-half minute time period for each part, examinees could be asked by the administrator to draw a line below the last item attempted. ETS should consider changing the instructions so that examinees use different symbols to mark numbers judged the same as well as numbers judged to be different.

The Ornamentation Test and the Elaboration Test require the examinee to decorate objects. Each decoration must be different and random marks and scribbles cannot be counted as designs. Some subjects used tactics such as numbering (1, 2, 3, 4, etc.) or lettering (v, w, x, y, z) a series of objects or writing personal names or titles on the objects. Although these responses may be slightly different in appearance, only the first in a series was scored as a "different" design, consistent with the investigators' interpretation of the figural fluency factor.

During the scoring of the Opposites Test and the Controlled Associations Test, many additions were made to the lists of examples of acceptable words. Each scorer was equipped with a dictionary or thesaurus, and recorded acceptable answers as they occurred. Lists were also kept of examinee answers judged as unacceptable after referral to a dictionary/thesaurus. The expanded lists were built and used with the intention of improving consistency within and among scorers. The last word presented in the ETS key for Part 1 of the Opposites Test is a synonym rather than antonym and is consequently an unacceptable answer for that item.

Finally, the Surface Development Test and the Figure Classification Test are among many in the Kit with instruction pages that note a correction for guessing will be applied during scoring. Applying a correction formula to these two hand-scored tests would be extremely difficult due to the varying number of response alternatives for items within each test. At the suggestion of Dr. Ekstrom and ETS, these two tests were scored by simply counting the number of correctly answered items.

Discussion

Experiences with 46 tests from the Kit of Factor-Referenced Tests provided valuable knowledge in the areas of their selection, reproduction, administration, and scoring. The test selection process was not detailed here but can be found in Augustin, Gillet, Guerrero, and Curran (1989). Guidance

concerning the reproduction, administration, and scoring of the 46 tests was presented and can be summarized as follows.

1. Print the test/s on a heavy paper to obtain a sufficient degree of opaqueness. The weight of 70# was found in this study to provide opacity within economical reason.

2. Conduct pilot administrations. The pilot should be conducted as a full administration to insure that the instructions are understandable, that the items are completable by the examinees (are of appropriate difficulty), and that the examinees follow any specific instructions (for example, examinees proceed from Part 1 to Part 2 or examinees put pencils down between memory span test items).

3. Correct instructions and items as indicated for the Making Groups Test and Storage Test and the item as indicated for the Vocabulary Test. Other revisions as indicated by the pilot administrations should be made pursuant with the approval of Dr Ruth Ekstrom.

4. Special attention must be made to the proctoring of the Kit tests, especially with the Finding A's Test. Perhaps more clearly marked parts might facilitate the examinees progress from Part 1 to Part 2. Increased monitoring should be maintained on the memory span and associative memory tests, as well.

5. Templates and transparencies are recommended to enhance scoring speed and accuracy and to aid in the independence of the scorings by the raters.

6. For some users the ease of scoring a test will determine whether the test is selected. One may think that the more objective a test is to score the more reliable (across raters) the scores will be. Inter-rater reliabilities for tests in this study were over .95 for even the most subjective scoring tests (category 3, Table 1). However subjective scoring tests are time-consuming. If resources are not limited, then the selection of tests based on objective/subjective scoring is not as much of an issue.

Overall, the experiences from this study were very valuable. Understandably, some of the guidance given here applies to any test or tests one might be considering. The use of the Kit tests is recommended by the authors and with careful planning and consideration of the guidance presented here, the Kit tests can be reproduced, administered, and scored without encountering major problems.

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Footnote

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Table 1

Observations on the Factor-Referenced Tests Used

Factor Name	Test Name	Scoring Category[a]	Test Observations[b]
Closure, Flexibility of	Hidden Patterns	1	
	Copying	2	5
Closure, Speed of	Gestalt Completion	2	6
	Concealed Words	1	
Closure, Verbal	Scrambled Words	2	6
	Incomplete Words	2	6
Fluency, Associational	Controlled Associations	2	5
	Opposites	2	5
Fluency, Expressional	Making Sentences	3	
	Arranging Words	3	
Fluency, Figural	Ornamentation	3	5
	Elaboration	3	5
Fluency, Ideational	Topics	3	
	Thing Categories	3	
Fluency, Word	Word Endings	2	
	Word Beginnings	2	
Induction	Letter Sets	1	
	Figure Classification	1	3,5
Integrative Processes	Calendar	1	1
	Following Directions	1	
Memory, Associative	Picture-Number	1	4
	Object-Number	1	4
Memory Span	Auditory Number Span	1	2
	Auditory Letter Span	1	2
Memory, Visual	Building Memory	1	4
	Map Memory	1	4
Number Facility	Addition	1	
	Subtraction & Multiplication	1	

(table continues)

Factor Name	Test Name	Scoring Category[a]	Test Observations[b]
Perceptual Speed	Finding A's	1	3
	Number Comparison	1	3,5
Reasoning, General	Arithmetic Aptitude	1	
	Necessary Arithmetic Operations	1	
Reasoning, Logical	Nonsense Syllogisms	1	
	Diagramming Relationships	1	
Spatial Orientation	Card Rotations	1	
	Cube Comparisons	1	
Spatial Scanning	Maze Tracing Speed	1	6
	Map Planning	1	2,6
Verbal Comprehension	Vocabulary I	1	1
	Vocabulary II	1	
Visualization	Paper Folding	1	
	Surface Development	1	3,5
Flexibility, Figural	Toothpicks	2	6
	Storage	1	1
Flexibility of Use	Combining Objects	2	6
	Making Groups	3	1,2

[a] 1 = Comprehensive answer key
2 = Noncomprehensive answer key
3 = No answer key

[b] 1 = Copy furnished by ETS requires correction before reproduction.
2 = Administration instructions require elaboration.
3 = Test structure/design requires special attention.
4 = Requires very close proctoring during testing.
5 = Elaboration of provided scoring procedures is suggested.
6 = Additional answers found for closed-ended items with answer keys.

Table 2

Factor-Referenced Tests with Additions to Answer Keys

Test	Part 1 Items	Part 2 Items
Gestalt Completion	6	15,19
Scrambled Words		47
Incomplete Words	48-50	51,52,54,56-58, 64-66,77-81,84,85
Maze Tracing Speed	Square #8	
Map Planning		35
Toothpicks	1-3,5	6-10
Combining Objects	2,6	17-19